

young cities

Developing Urban Energy Efficiency
Tehrān-Karaj

Young Cities Research Briefs | 05

Energy Concepts for the Shahre Javan Community

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1 Introduction

The aim of the Young Cities Team 2 sub-project “Energy Infrastructure systems” consists of the development and the design of energy efficient buildings and energy supply systems for new Towns in Iran.

This document gives an overview over the design and the development of the energy supply systems for the 35 ha pilot area in Hashtgerd New Town (Share Javan Community). In general, these energy concepts are suitable for the supply of all types of buildings (residential, commercial, cultural, etc.), but in this paper the focus lies on the energy supply of residential buildings.

It is possible to reach the aim “energy efficiency” through several methods, for example by using common Iranian building technologies in different ways, or through the improvement of these technologies. Another possibility lies in the use of available renewable energy sources, for example the very high potential of the solar irradiation in combination with solar thermal technologies for heating and cooling. Energy efficiency can be also realized with new introduced building technologies, such as centralized, semi-centralized and de-centralized energy supply systems, based on co-and tri-generation¹ technologies and district heating networks.

The first step was a climate analysis for the location Hashtgerd New Town as the base for the energy demand analysis and for the determination of the environment energy potential. Based on these results, an energy demand analysis for the different residential building types was carried out. The next step was the design of four efficient energy supply systems, which were compared to each other regarding to their primary energy demand, their carbon dioxide emissions and their energetic life cycle costs. In the end, one of the systems is recommended as the “favorite system” for the supply of the Share Javan Community.

¹ Co-generation: Combined heat and electricity production

Tri-generation: Combined heat, cold and electricity production

2 Climate Analysis

A weather data base is important for the energetic calculations and needs to be adjusted to the local climate. The listing of hourly values represents the climate Hashtgerd New Town over the period of a whole year.

Following parameters are used in the weather data base: Geographic coordinates (longitude and latitude), air temperature, solar irradiation, relative humidity and wind velocities/directions. The weather data set for Hashtgerd New Town was generated with Meteonorm 7, a global meteorological data-base for engineers and planners [2]. The values of Figure 1 are characteristic for the site of Hashtgerd. This Figure shows the average air temperature and relative humidity of the different months.

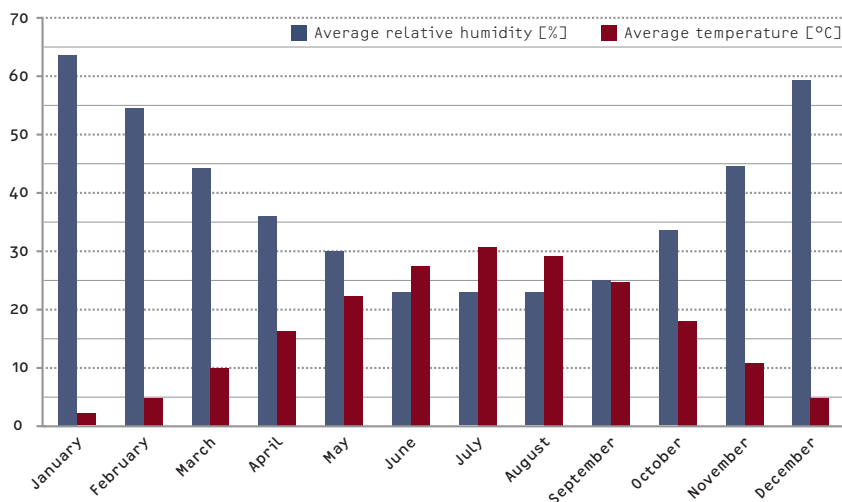


Fig. 1: Monthly average values of the relative humidity and air temperature in Hashtgerd New Town. The data set was generated with Meteonorm 6

The monthly average temperature ranges from 2.2°C in January up to 30.8°C in July (difference: 28.6 K). The comparison of the annual hourly maximum values of temperature shows a difference of 47.3 K. The wide range of temperatures during the periods of the year is visible. The values of the relative humidity demonstrate the dry summertime in Hashtgerd.

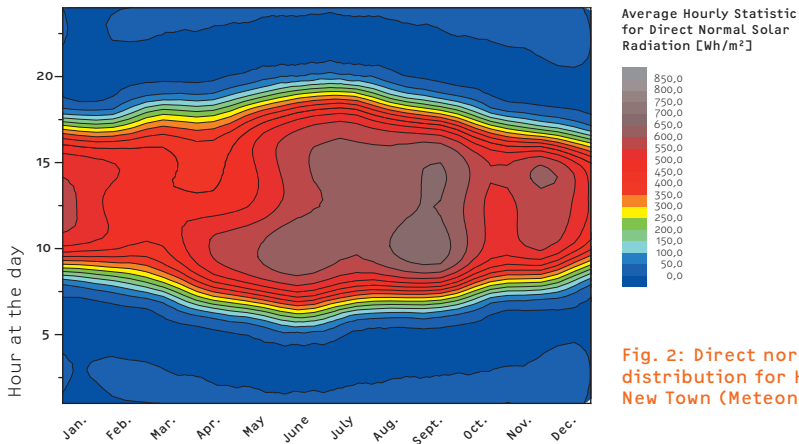


Fig. 2: Direct normal radiation distribution for Hashtgerd New Town (Meteonorm 7 data set)

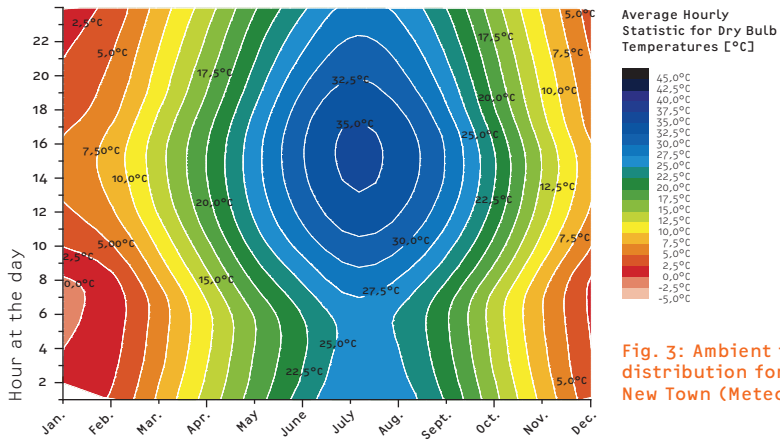


Fig. 3: Ambient temperature distribution for Hashtgerd New Town (Meteonorm 7 data set)

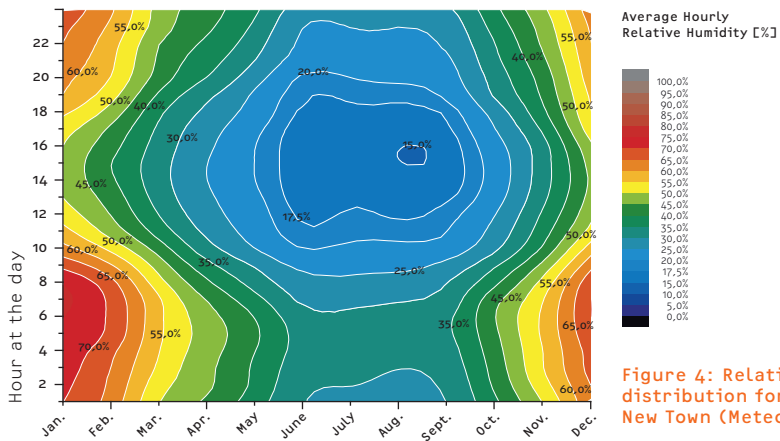


Figure 4: Relative humidity distribution for Hashtgerd New Town (Meteonorm 7 data set)

The Hashtgerd climate is influenced by the Alborz mountains in the north and the plain in the south. Hashtgerd is located at the southern branches of the Alborz mountains on an altitude of 1,200 m above sea level. The Caspian Sea has no climatic influence for the region of Hashtgerd, the mountains work as a barrier.

Because of the little occurrence of rainfalls due to the barrier of the Alborz mountains which stops the clouds, the relative humidity is very low and therefore the solar irradiation very high. The yearly global horizontal irradiation in Hashtgerd amounts 1,803 kW h/m²a, this is nearly the double of the German irradiation.

The Figures 2, 3 and 4 display the average hourly values for the direct normal radiation, the average ambient temperature and the average relative humidity in a raster diagram. The average hourly maximum of the direct normal radiation (Figure 2) occurs at the end of the summer (end of august) in the late morning (between 10 and 12 o'clock am). Figure 3 shows the maximum average hourly ambient temperature (above 35°C) and its maximum is in the early afternoon in the midsummer. At the same time, the relative humidity is at its lowest (Figure 4).

3 Energy Demand Analysis

A detailed energy demand analysis is very important for the design of the energy infrastructure systems. The analysis considers the building physics and the energy efficiency of the residential buildings in detail. The demand of the other buildings types are approximated with coarse mean values, because at present, detail planning fundamentals don't exist.

3.1 Building Distribution

Within the research project Young Cities (www.youngcities.de), several kinds of energy efficient buildings (residential, infrastructure and cultural buildings) are developed from researchers at the TU Berlin (Ph. Wehage, F. Nasrollahi and A. Böhm). These buildings are distributed over the Share Javan Community (see Figure 5). The residential buildings are divided into 4 building types, regarding to their different facade length and their different zonal distribution. In Figure 5, different residential buildings types are illustrated.

The energy demand studies for the residential buildings within the Share Javan Community were done for three different material settings of the building elements. These material settings are:

1. materials defined from the German researchers with an effectively improved energy efficiency,
2. same materials as an existing Iranian building (building as usual),
3. material definitions according to the Iranian energy code (Code 19 [5])

In addition to the materiality, the geometry of the façade was changed. The first façade geometry was a geometry with very large visible windows. The second façade geometry was developed in dependence on a traditional Iranian facade with a huge number of very small windows. All these studies were executed with the use of dynamic thermal building simulation tools (Autodesk Ecotect [3] and EnergyPlus [4]).

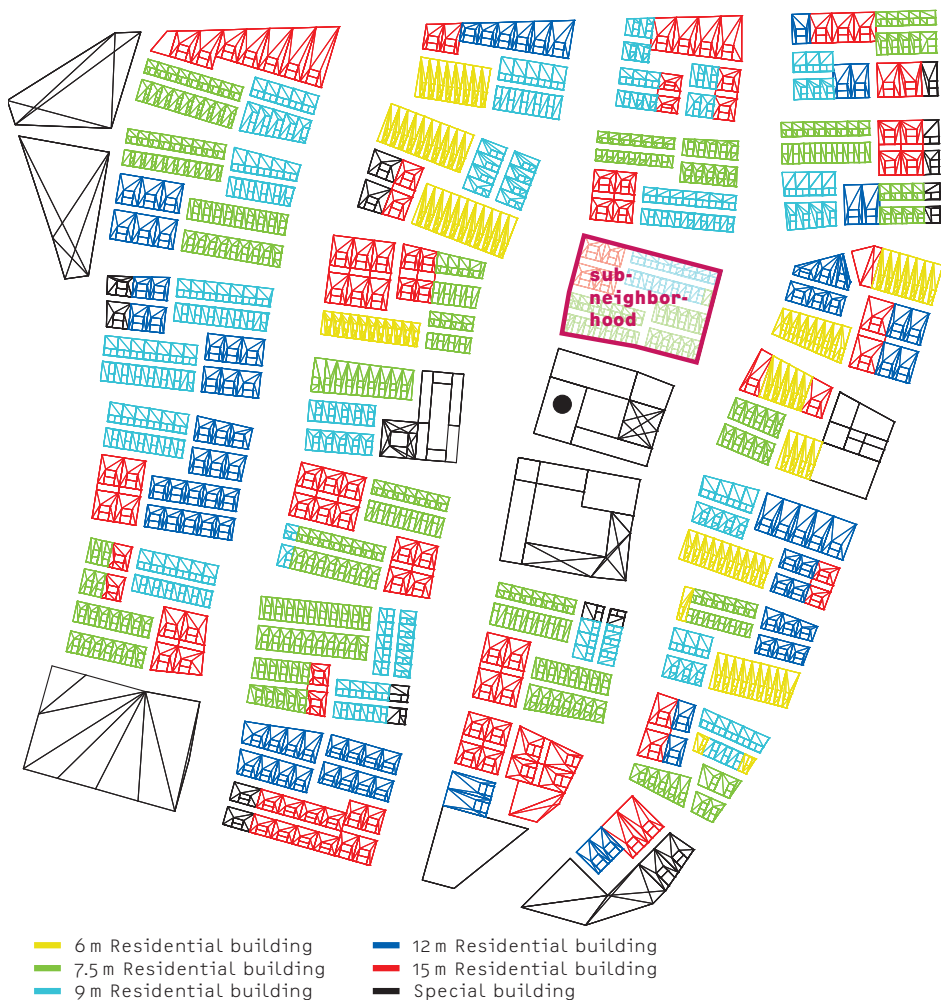


Fig. 5: Building distribution within the Share Javan Community

3.2 Thermal Building Simulation

Figure 6 shows the simulation model of the 9 m residential building (with the traditional Iranian façade) with the shadow ranges from 9:00 am to 5:00 pm on 21 Jun.

The thermal building simulation calculates the chronological sequence of average zonal values (e.g. air temperature, heating load, cooling load) for a long period of time (for example over the summer). Further, different operating modes of ventilation, heating or cooling are analyzed. The interaction of the facade (external thermal loads), the ventilation (natural / mechanical) and the internal thermal loads (occupants, lightening, etc.) and the thermal

storage capacity of different building elements are considered. The calculation results are carried out in hourly data for a whole year.

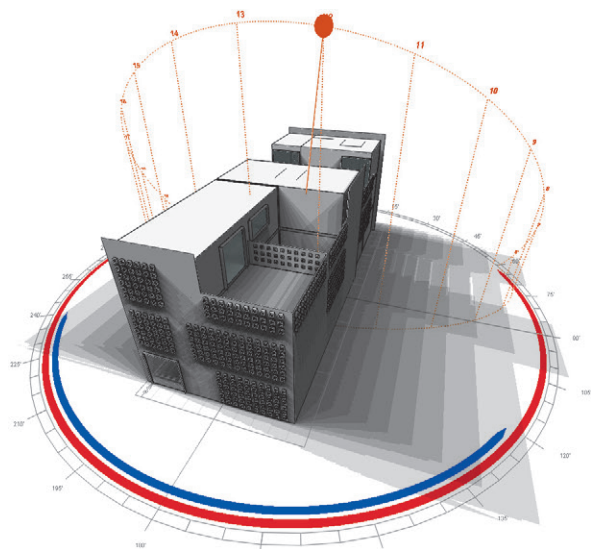


Fig. 6: Simulation model of the 9 m residential building, produced by Ecotect Analysis [3]

3.3 Results

3.3.1 Single buildings

The specific heating and cooling energy demand (see Figure 7) ranges from 24.6 kWh/m²a to 39.8 kWh/m²a for the single residential building types. Almost every analyzed building type has a higher demand of specific heating energy than specific cooling energy. The house in the center of the 6m wide housing typology is the only building, which has a greater demand of cooling energy than heating energy. The high solar gains of the façades causes this effect.

The energy load for the whole Share Javan Community includes the load of all the residential and other buildings. The overall load is 11.3 MW (33.6 W/m²) for heating and 10 MW (31.9 W/m²) for cooling. Figure 8 shows the different heating and cooling loads for each sub-neighborhood².

Figure 9 shows the hourly demand values and the annual load duration curve for heating and cooling for the sum of the buildings on the pilot area. The duration for heating and cooling is nearly the same (approximately 4,000 hours per year).

² Sub-neighborhood: One sub-neighborhood consists of about 18 residential buildings or several non-residential buildings (see example sub-neighborhood in figure 5).

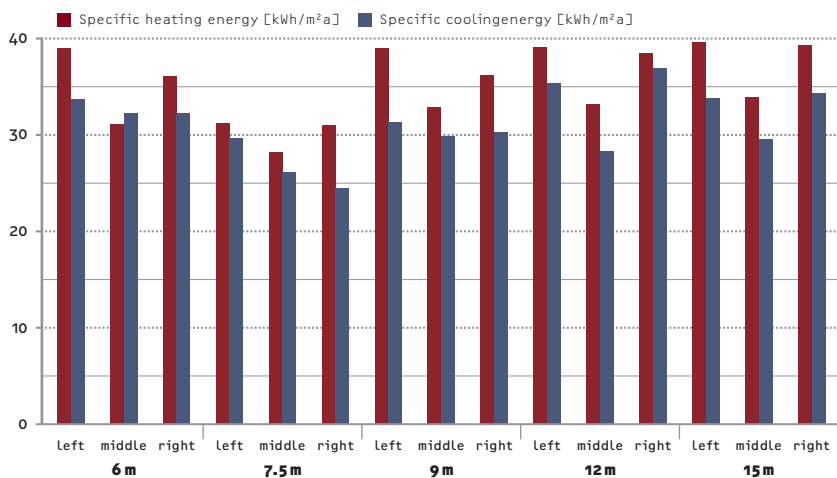


Fig. 7: Comparison of specific heating and cooling demand of each single residential building

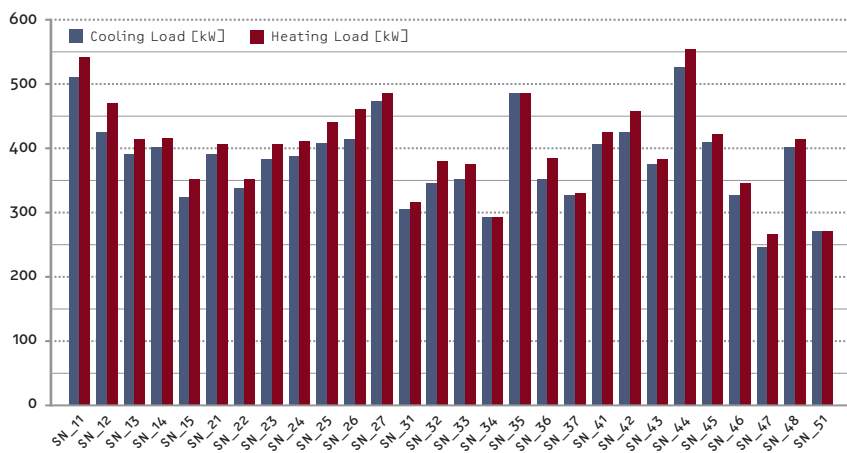


Fig. 8: Comparison of the heating and cooling load for each sub-neighborhood of the Share Javan Community

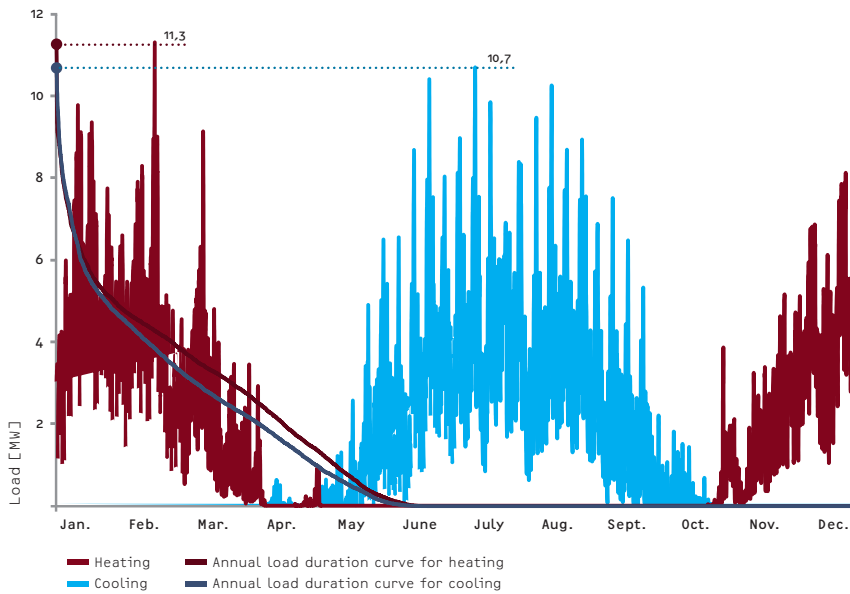


Fig. 9: Heating and cooling load for the Share Javan Community

4 Energy Supply Systems

Four different energy efficient supply systems were designed and compared under each other and also with a reference system (a conventional Iranian energy supply system) regarding to their primary energy demand, their carbon dioxide emissions and their energetic life cycle costs. The building envelope of the residential building with the reference system has an energy efficiency according the Iranian energy code (Code 19[5]). Against that, the envelopes of the buildings with the improved energy supply systems have an effectively improved energy efficiency, which is the base of the energy demand analysis of chapter 3.

4.1 Reference System: Conventional Iranian Energy Supply System for Residential Buildings (Reference) on Building Level (De-Central System)

This reference system represents the widely-used Iranian energy supply system for residential buildings in hot and dry climate regions. Here, the potable and heating hot water demand is centrally produced by a natural gas-boiler (without condensing technology) in the basement. In addition, the cooling demand is produced by an evaporation chiller (without condensing technology) in the basement.

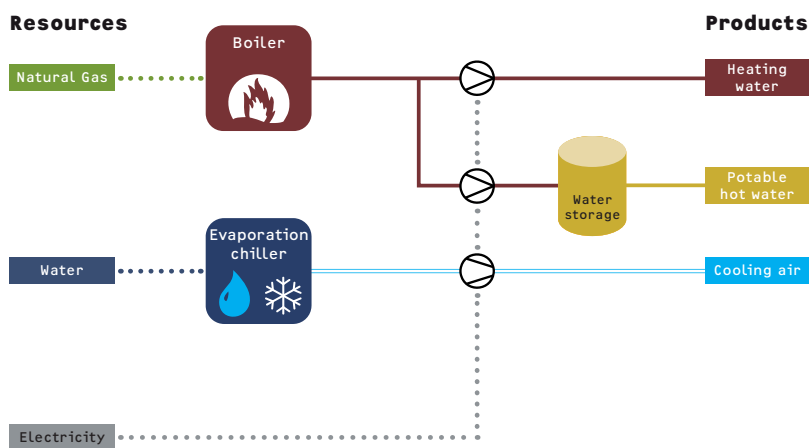


Fig. 10: Schematic illustration of the energy supply system of the conventional Iranian system

All components of the heating system are almost non-insulated. The heat is transferred by convectors into the rooms. For space cooling during the summer, an evaporation chiller on the roof of the building for each unit is installed. This chiller uses the condensing enthalpy for the production of cold air, which is distributed through a single duct system in the respective zones with up to 25–air changes per hour. An exhaust duct system does not exist and the waste air is discharged through leaks, gaps or open windows to the building environment. Due to the high air exchange rates and the desired low air temperatures in summer, the water and electricity demand of the evaporation chiller is enormous (350 l/day of water and 2,900 kWh of electricity. This is nearly the same amount of water and electricity as a German 2 person household needs).

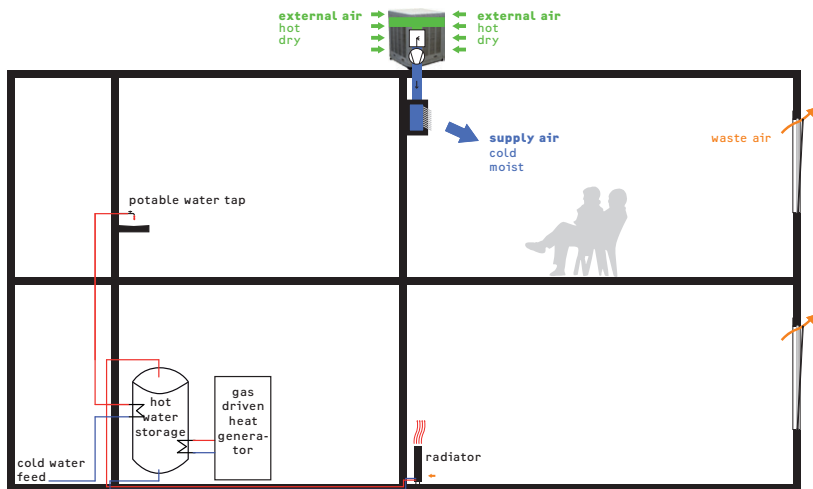


Fig. 11: Energy system of the conventional Iranian system for heating and cooling.

System Configuration:

The production, distribution and the transfer will take place at building level. The hot water is produced centrally in the basement of the building and a classical piping network transports the hot water to the radiators. In contrast to the heat, the cold air is produced for each unit by an adiabatic evaporative chiller on the rooftop of the building and an air duct system transports the cooled air to wall outlets where the air passes into the zones.

The production, distribution and the transfer will take place at building level (cold on the roof, heat in the basement of the building).

4.2 Improved Iranian Cooling Technology and Modified Heating System with Solar Thermal Collectors and Condensing Technologies on Building Level (De-Central System)

The improved Iranian cooling system is an extension of the conventional Iranian system with a few additional components (heat recovery and second air duct). The production, distribution and transfer will take place on building level (cold on the roof, heat in the basement and on solar thermal collectors on the roof of the building).

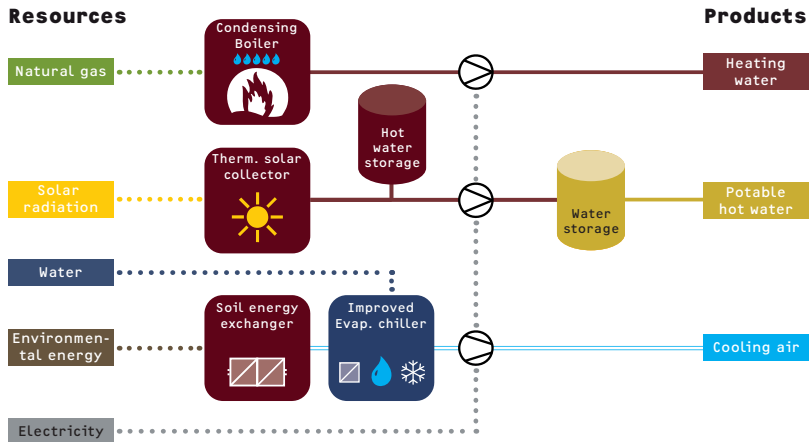


Fig. 12: Schematic illustration energy system of the improved heating and cooling system.

Furthermore, all components of the heating system (thermal storages, distribution pipes etc.) were covered with an insulation for a significant reduction of the thermal losses. In addition, thermal solar collectors were installed on the roof of the building. The gained solar energy is primarily used for domestic hot water supply. Secondarily, the heating system is partly supported.

System Configuration:

The production of hot water is made centrally in the basement of the building with a condensing gas boiler and a thermal solar collector system on the top of the building. The hot water is transported with very well-insulated pipes within the heating system to an underfloor heating system (this system is used because of the lower temperature level of the thermal solar collectors). According to the centrally heat production in the basement, the cold production is also centralized and takes place on the rooftop of the building.

The cold air is produced by a central on the rooftop of the building. Within this cold-central, the pre-cooled external air (caused by a soil heat exchanger) passes the heat recovery unit and gets colder (because of the waste air en-

ergy content) and gets cooled down by an adiabatic evaporative cooler. The cooled air is transported by the use of air ducts to the outlets. The exhaust air passes with a second air duct the heat recovery unit and afterwards through the duct to the environment.

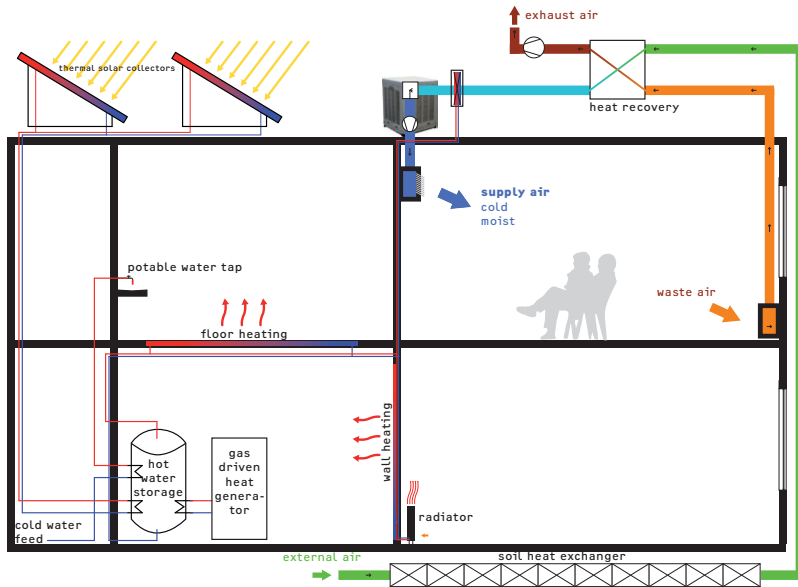


Fig. 13: Energy plant system of the improved Iranian system for heating and cooling

4.3 Compression Cooling System with Photovoltaic Produced Electricity and Improved Heating System on Building Level (De-Centralized System)

The conventional adiabatic evaporative air cooling system is replaced with a cold water supply system. Here, the needed electricity for the compression chiller is produced by photovoltaic modules. If an over-production of electricity occurs, it can be fed into the grid or stored in a battery storage.

To increase the COP (coefficient of performance) of the compression chiller, a cooling tower can be used, which would, however, again increase the demand for water. The use of such a re-cooling tower is to be discouraged due to the project context. The heating and potable water system is the same as the one described in the improved Iranian cooling system.

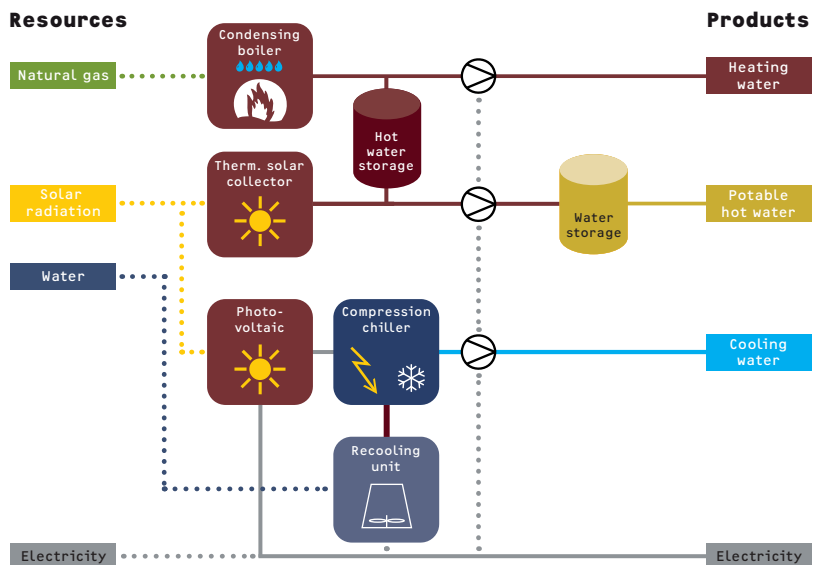


Fig. 14: Schematic illustration of the third system. Compression cooling system with photovoltaic produced electricity and improved heating system on building level (de-centralized system)

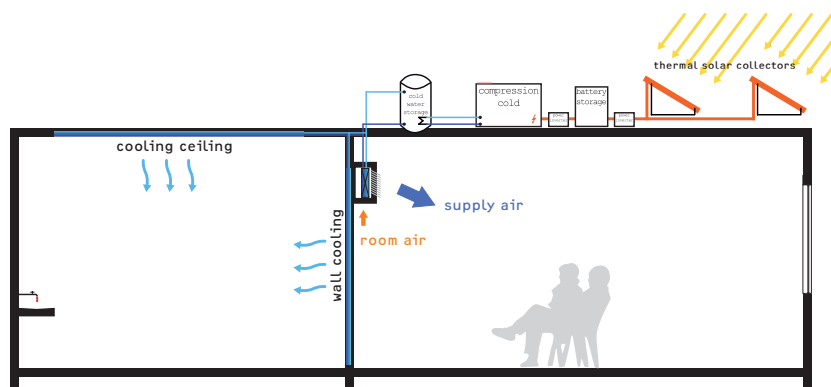


Fig. 15: Energy plant system by cooling with photovoltaic produced electricity and improved heating system on building level (de-central system)

4.4 Semi-Central System with a Thermal Driven Cooling System and a Co-Generation Plant for The Heating and Electricity Demand on Sub-Neighborhood Level

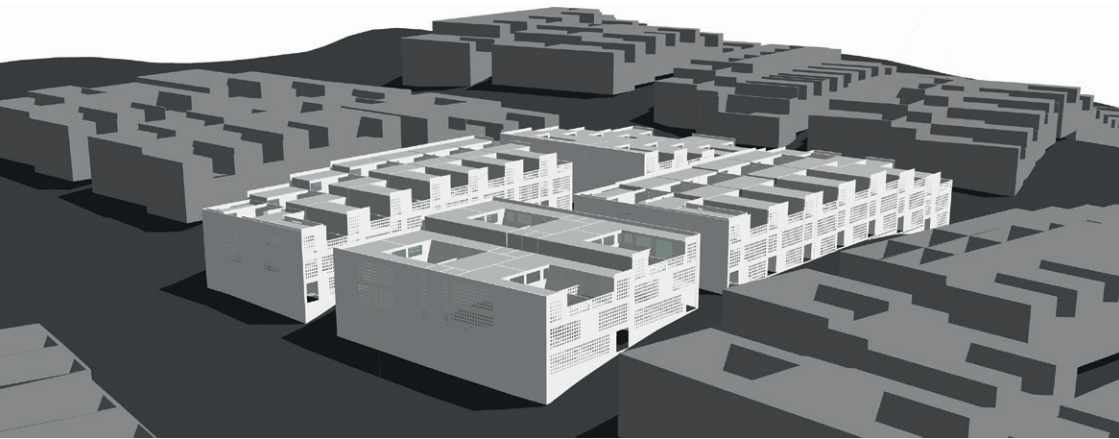
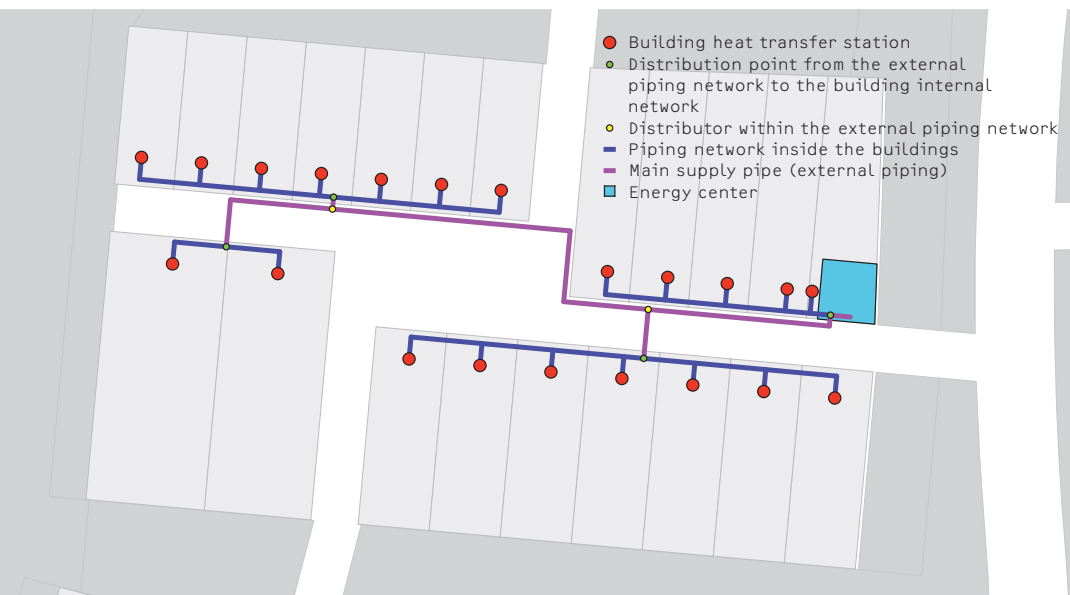


Fig. 16: Thermal building Simulation model of a sub-neighborhood

The used technology for building cooling is the conversion of heat to cold by use of an absorption chiller, which supplies a whole sub-neighborhood. The needed heat comes from the thermal solar collector fields (on the building roofs (Figure 16 shows the thermal building simulation model of the sub-neighborhood)). If there is a limited gain of heat from the collectors, the co-generation plant (one for a whole sub-neighborhood, see Figure 17 the blue rectangle) produces additional thermal energy. Because of the cold water storage, a chiller for the peak cooling demand could be dispensed.

Fig. 17: Semi-central energy production



Every absorption chiller needs a re-cooling unit, mostly all of them are designed as wet-cooling towers, which require a considerable amount of water. Figure 18 shows a schematic overview about the needed resources and the produced energy products with the main energy transformation components.

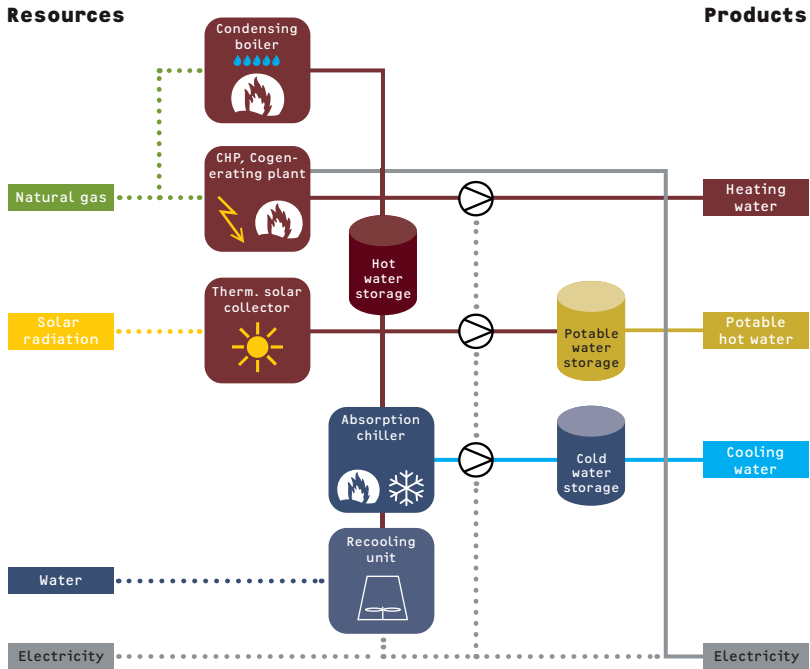


Fig. 18: Schematic illustration Flow chart of the semi-central system on sub-neighborhood level.

4.5 Central Heat Generation with a Co-Generation Plant on the 35 ha Area and Semi-Central Thermal Driven Cooling System on Sub-Neighborhood Level-Neighborhood Level

This central system is nearly similar to the previous system (chapter 4.4), but the heat production (if there is an undersupply by the thermal collectors) is centralized for the entire 35 ha site (see Figure 19). The cold production is identical to 4.4 in a sub-neighborhood by an absorption chiller system.

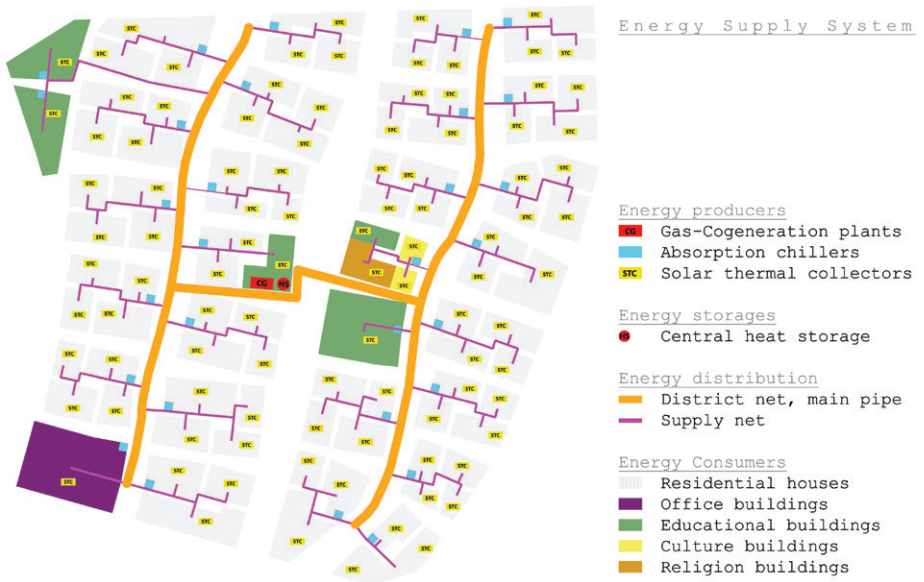


Fig. 19: Central heat production with distribution net and semi-centrals for cold production

5 Conclusion

For all these different energy concepts, an analysis for the energy demand, the live-cycle cost and the CO₂ emission were done. For a first estimation, the investment costs and primary energy factors are calculated with German values. These European prices were reduced with regional factors (from “BKI Baukosteninformationszentrum” [6]) to the economic situation in Iran. Because of the unknown Iranian primary energy factors, the German values were retained. The recommended system is the “Improved Iranian cooling technologies and modified heating system” from chapter 4.2. The components of this system are nearly all available or produceable in Iran, furthermore, the used technologies are known in Iran.

Facts of the recommended system are:

The cooling system is an improvement of the commonly used air conditioning technology in Iran (an additional air duct, a further ventilator and a heat recovery unit for each flat).

- The technology for heating and the hot water generation is a worldwide used technology and consists mainly of a condensing boiler and solar thermal systems.
- The recommended system is just on single building level, therefore the implementation is much easier than a centralized system.

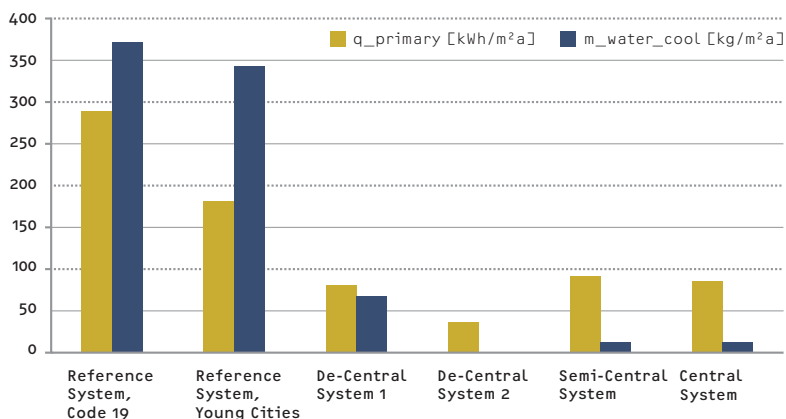


Fig. 20: Primary energy and water demand of the different systems

In Figure 20 is the water and primary energy demand shown. The recommended system saves around 73 percent of primary energy (against the reference system Code 19) and more than 80 percent of water.

The investment costs of the recommended system are moderate (see figure 21) and the life-cycle costs are very low. The CO₂ reduction against the reference system Code 19 account 72 percent in the recommended system.

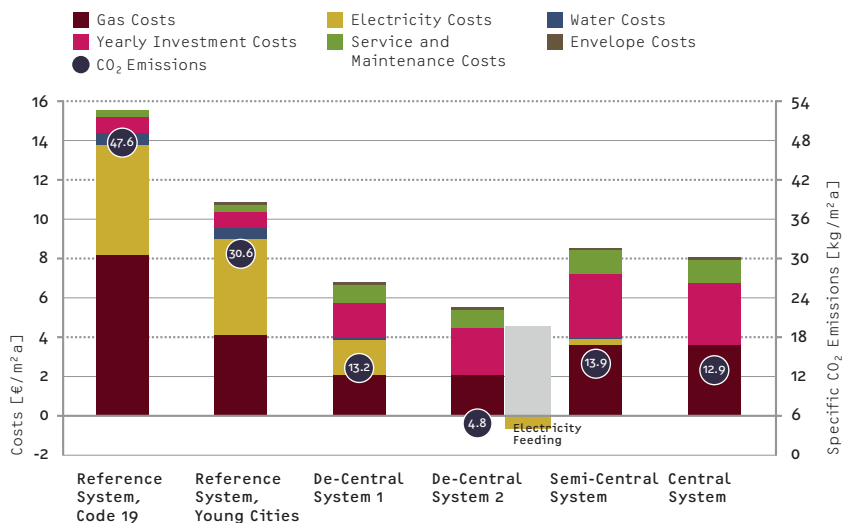


Fig. 21: Costs and CO₂ emissions of the different regarded systems

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